ETHOXOFUME© 1000 [ETHYLENE OXIDE] — A NICHE METHYL BROMIDE ALTERNATIVE.

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Ethylene oxide (C_2H_4O = EtO) is produced by oxidation of ethylene with oxygen at circa 250 °C over a catalyst comprising metallic silver supported on alumina [>15 million tonnes of ethylene oxide is produced annually]. EtO is the chief precursor to ethylene glycol (automotive coolant and antifreeze) and other high-volume chemicals (surfactants, ethanolamine etc).

For over eighty years EtO has been referenced as a sterilant / fumigant. EtO is lethal to most bacteria, viruses, moulds, insects and their eggs. Historically as an insecticide, EtO found application in the fumigation of bulk grain in recirculating systems and in the vacuum fumigation of food and tobacco. EtO is still widely used in "cold" sterilisation [temperature 50°C versus steam sterilisation >100°C] of medical devices and instruments. The sterilisation of foodstuffs and spices has been discontinued because of chlorohydrins residue issues (reaction of EtO with salt). EtO is a potential alternative for ozone depleting methyl bromide (MeBr)

Hazards:
Ethylene oxide is toxic by inhalation with an LD_{50} of 330 mg/kg. Laboratory animals exposed to ethylene oxide for their entire lives have had a higher incidence of liver cancer. EtO is classified as carcinogenic to humans by the International Agency for Research on Cancer (IARC). Occupational Exposure Limits: TLV-TWA [1 ppm]; OEL (UK)-LTEL [5 ppm].

Packaged Non-Flammable Mixture - EtO/CO_2: Ethylene oxide is a colourless, highly flammable gas [LEL=3% v/v in air] which liquefies at 10.9°C. Jones & Kennedy (1930) solved the EtO flammability issue by mixing 12% v/v EtO in CO_2. The internationally recognised non-flammable mixture is 9% v/v EtO in CO_2. The issue of flammability restricting usage of fumigants was circumvented by the Jones (1933) publication which detailed a list of non-flammable fumigants including EtO (12% v/v), ethyl formate (14% v/v) and propylene oxide (8% v/v) in CO_2.

On-site Non-Flammable Mixture - EtO/Air: The on-site mixing of EtO and Air is an option however the EtO must be kept below the 3% v/v lower flammability limit. This can be achieved by the addition of EtO to recycled air from the space being fumigated and maintaining the EtO concentration less than 54 g/m^3 (3% v/v). Forced draught recirculation using high velocity fans has the additional benefits of achieving uniform distribution; allowing the addition of EtO to compensate for losses associated with leaks / sorption and extracting EtO to enable capture / destruction on completion of fumigation. (EtO is easily burnt by venting via an incinerator / thermal oxidiser / catalytic converter. On completion of the fumigation the EtO/Air mixture can be exhausted using the high pressure fan and destroyed by mixing with the air supply to a "burner" where it is converted to carbon dioxide and water. Other EtO capture and destruction options include converting to ethylene glycol by scrubbing with 5% aqueous sulphuric acid or adsorption onto activated carbon followed by subsequent destruction or burial).

EtO/Vacuum:
Fumigations using ETHOXOFUME 1000 [EtO], under specific directions by the Australian Quarantine Inspection Service (AQIS), are conducted at approved facilities. These EtO fumigations are carried out using vacuum chambers to treat non-food import and export commodities. [AQIS Guidelines - Ethylene Oxide: T9020: Initial minimum vacuum of 50kPa at 1200g/m^3 for 5 hours at 50^oC; or 1500g/m^3 for 24 hours at 21^oC].

Efficacy of EtO and MeBr:
Reported Ct product of fumigants for the control of various species of insects (Munro, 1969) showed EtO and MeBr have similar efficacy. While the Ct favours MeBr (M.Wt. = 94.94) this is more than neutralized by the higher concentration achieved using ethylene oxide (M.Wt. = 44.05) e.g. a dose rate of 48 g/m^3 results in a concentration of 1.2% v/v for MeBr and 2.7% v/v for EtO. The molecular weight difference between MeBr and EtO results in the distinct differences in dosage and concentrations e.g. dose of 1 g/m^3 gives 257ppm v/v (MeBr) and 555ppm v/v (EtO) respectively.

As the MeBr low concentration and high Ct neutralises any differences, the recommended dose rate for methyl bromide and ethylene oxide should be similar. The recommended 48 g/m^3 (2.7% v/v) dose is attractive as it achieves an EtO level below the flammability level in air and this concentration should be efficacious in less than 12 hour exposure time.

While ethylene oxide hasn't the methyl bromide ozone depletion issues it is a known carcinogen and OH&S issues require significant more aeration than methyl bromide. As with existing sterilisation practice and registered label recommendations the aeration clearance level for ethylene oxide is the TLV i.e. 1 ppm v/v.

Soil Fumigation:
Ethylene oxide kills fungi in soil and microbial analysis indicated that EtO treatment is an effective soil sterilant compared to autoclaving and heat treatment. EtO modifies some soil parameters, but the changes are of a minor importance (Gennari et al 1987). The high solubility in water (~350g/L) and the need to reduce the flammability hazard suggests "in-line" fumigation application an attractive option. The reaction of EtO with water forming ethylene glycol should ensure there is minimal release of EtO in soil fumigation applications. Reports that ethylene glycol undergoes rapid biodegradation in aerobic and anaerobic environments supports potential soil applications.

References:
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